Transportation of object by a chemical reaction

Department of Physics, Graduate School of Science, Kyoto University.
Takeshi Asahi, [1] Takatoshi Ichino, [2] Hiroyuki Kitahata

生物は等温条件下で化学エネルギーをベクトル的な仕事に直接変換しつつ運動しており、そのメカニズムは未だ明らかではない。生体内でのエネルギーの損失は非常に少なく、その機構の解明は多くの恩恵をもたらすであろう。我々は、化学反応からベクトル的な仕事を取り出すために、Belousov-Zhabotinsky(BZ)反応が引き起こす対流現象を用いて物体を一方向へ輸送する系を作り、化学ー機械エネルギー変換のメカニズムについて考察した。

Living organisms dissipate chemical energy to generate vectorial work under isothermal conditions. According to the Curie-Prigogine principle, coupling between scalar and vectorial variables is prohibited under isotropic conditions within the framework of linear non-equilibrium theory. It is important to clarify the intrinsic machanism of energy transduction from scalar chemical energy into vectorial mechanical work.

Recently, we reported the periodic motion of a droplet driven by Belousov-Zhabotinsky(BZ) reaction, which is well-known as an oscillatory chemcal reaction.[1] Under the well-stirred conditions, BZ medium shows a rhythmic change between oxidized and reduced states. When the medium is allowed to stand without stirring, chemcal waves are generated spontaneously, forming target or spiral patterns. It was reported that convective flow is induced by a change in interfacial tension between oxidized and reduced states in the BZ reaction.[2] Thus, the directed motion of BZ droplet is generated by chemical waves, which is regarded as a kind of chemcal engine working under isothermal conditions. However, the BZ droplet returns to the initial position, so total moving distance is zero.[1] In this paper, we will show that a small object can be directionally transported by using a BZ reaction through the transmission of the chemical wave.

We used exitable BZ medium to transport a small object. As an object, a piece of paper with the size of about 2mm×2mm were used . A chemical wave was initiated using a silver wire. The experimental system is shown in Fig. 1(a). Figure 1(b) shows the motion of the object floating on the interface between BZ medium and oleic acid. To control the transportation of the object,

[1]E-mail: asahi@chem.scphys.kyoto-u.ac.jp
[2]Present address: Kinki University

we genarated the chemical wave at another end. At first, the object was moved toward to the origin of the chemical wave, then stopped at the tail of the chemical wave, and it was attracted to the propagating wave. the chemical wave dissapeard by colliding with another one, and the objoct stopped at the present point. Thus, we could transport the object translationally. It can be said that chemcal energy is transduced into vectorial work in this system.

This result may be helpful for understanding the mechanism of chemo-mechanical enegy transduction in living systems. In the further study, we will compare the efficiency of this system with the other ones.

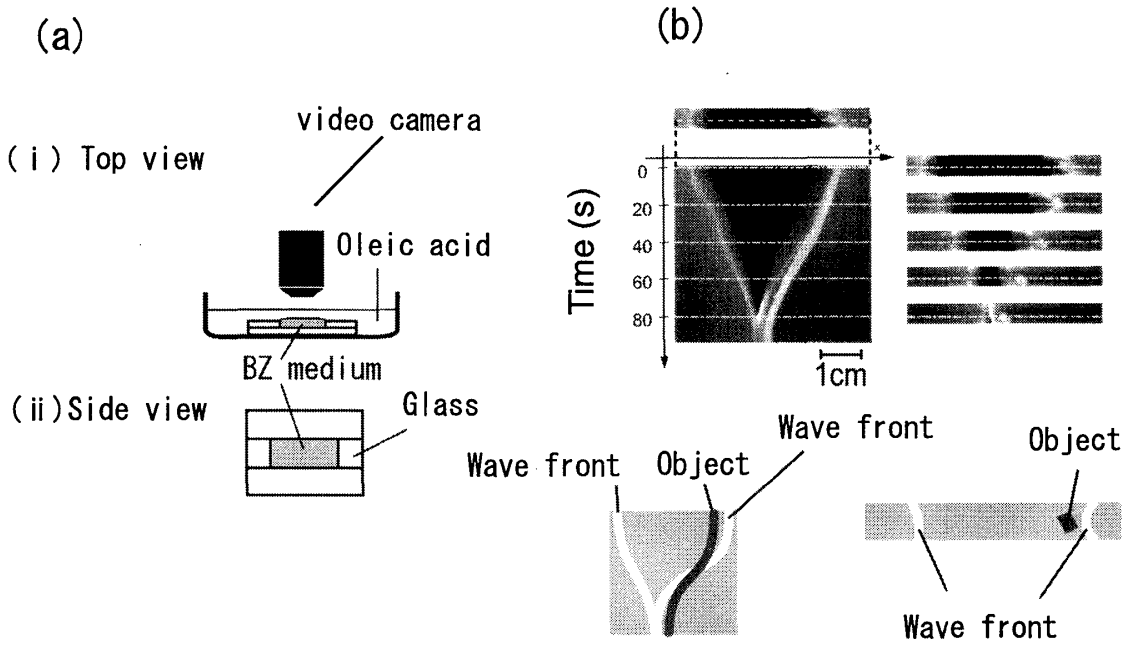

Figure 1: Experimental results on transportaion of a piece of paper. (a) Experimental system. (b)Spatio-temporal plot for directional intersection at the broken line in the upper picture. The bright and dark regions correspond to the oxidized and reduced states, respectively.

Acknowledgment

The Author would like to thank Professor K. Yoshikawa for his helpful discussion.

References

[1] H. Kitahata, R. Aihara, N. Magome, and K. Yoshikawa, J. Chem. Phys. **116** (2002), 5666.

[2] K. Yoshikawa, T. Kusumi, M, Ukitsu, and S. Nakata, Chem. Phys. Lett. **211** (1993), 211.